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(54) **FLUID LEVEL MEASUREMENT SYSTEM AND METHOD**

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(60) Provisional application No. 61/320,033, filed on Apr. 1, 2010.

(51) **Int. Cl.**
B60H 1/32 (2006.01)
G01F 23/296 (2006.01)

(52) **U.S. Cl.**
CPC ***G01F 23/2962*** (2013.01); ***G01F 23/2968*** (2013.01)

(58) **Field of Classification Search**
USPC .... 73/1.73, 290 V; 62/239
See application file for complete search history.

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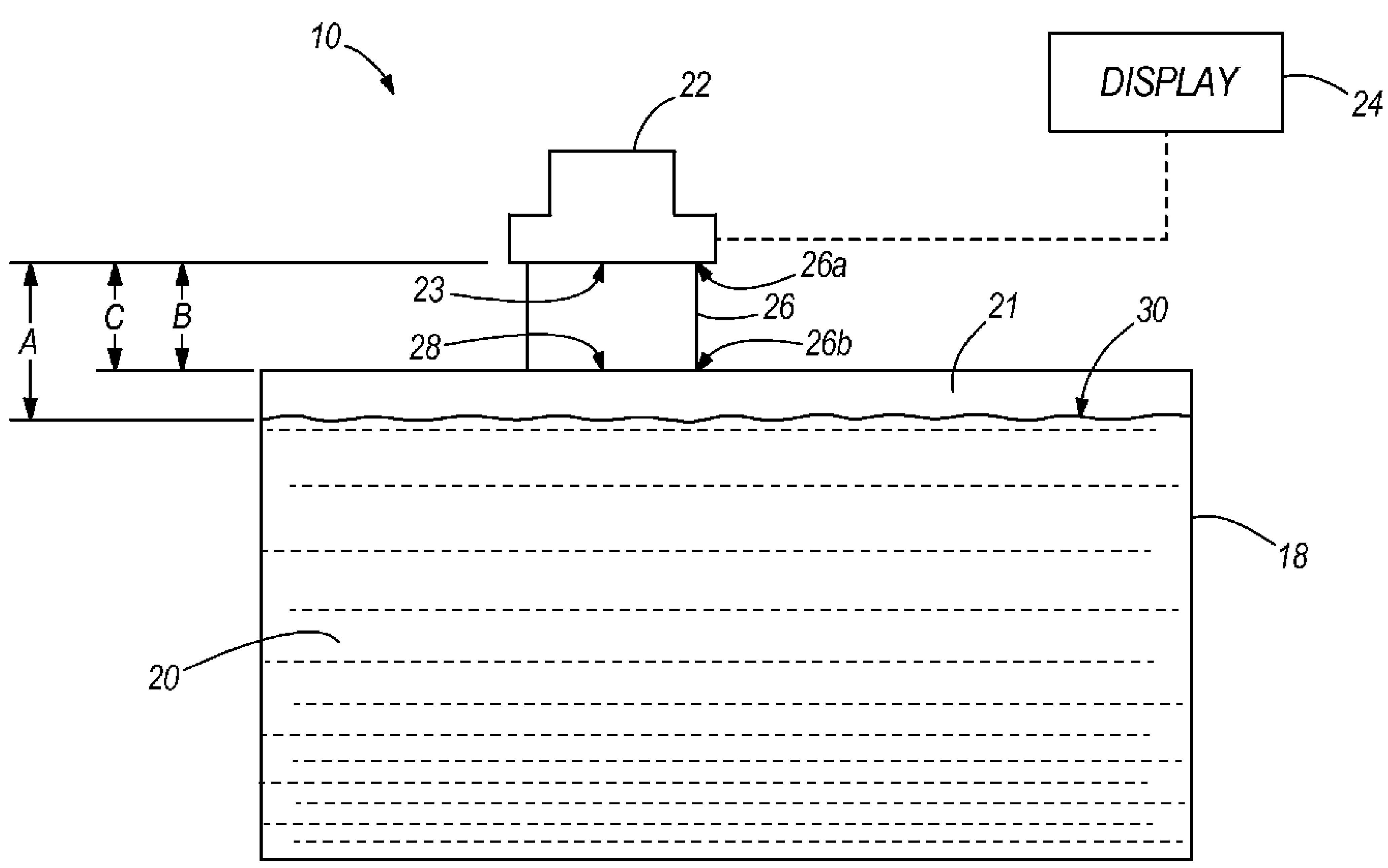
(57) **ABSTRACT**

A method for measuring a fluid level in a tank containing a fluid for a transportable temperature controlled space. The method includes providing a temperature control system for the transportable temperature controlled space, providing a fluid level sensor for sensing a fluid level in the tank, generating fluid level signals with the fluid level sensor indicative of the fluid level in the tank, providing a fluid level algorithm for receiving the fluid level signals from the fluid level sensor and computing the fluid level in the tank, and inhibiting nondeterministic fluid level signals from being introduced to the fluid level algorithm.

18 Claims, 6 Drawing Sheets



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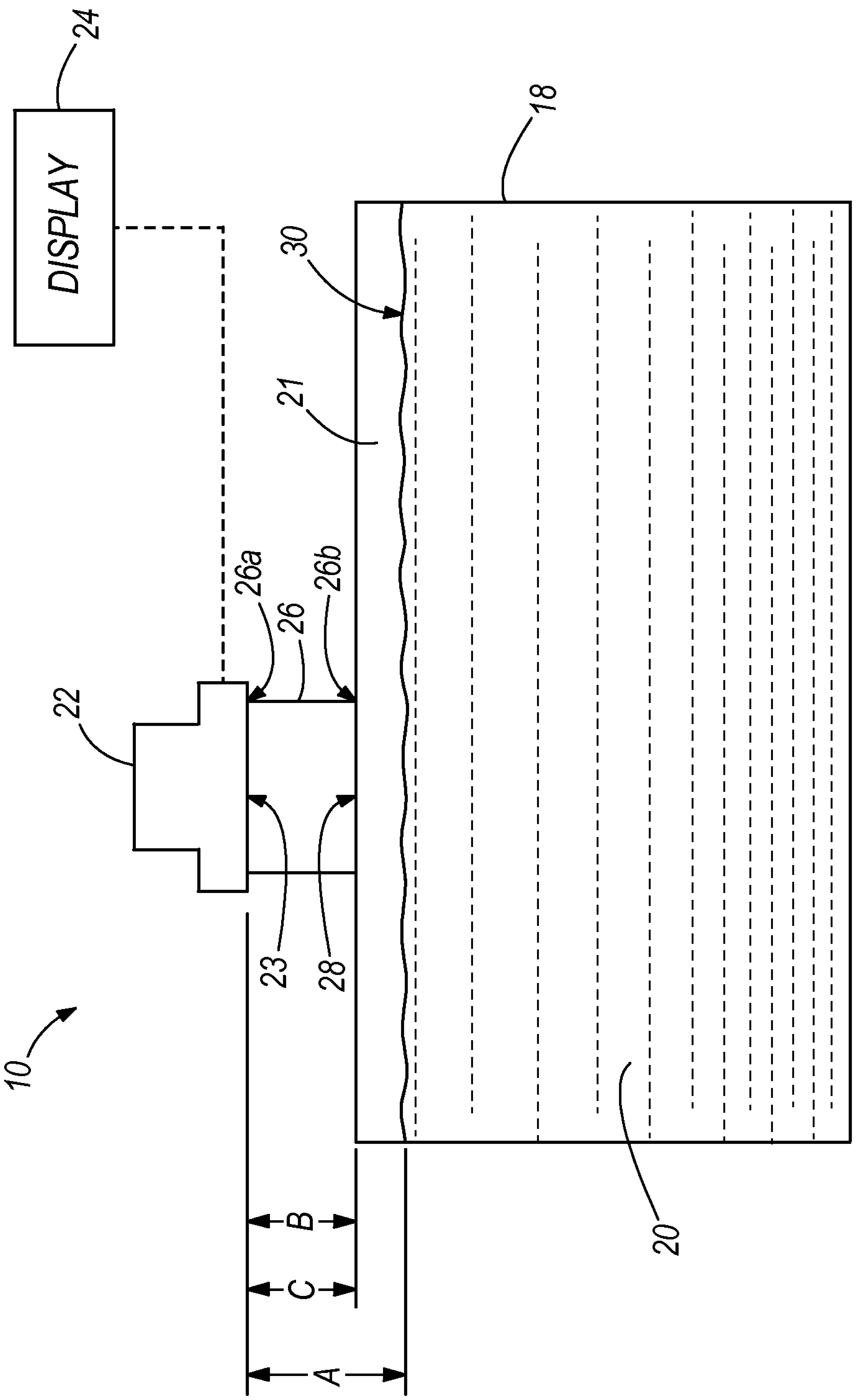


FIG. 1

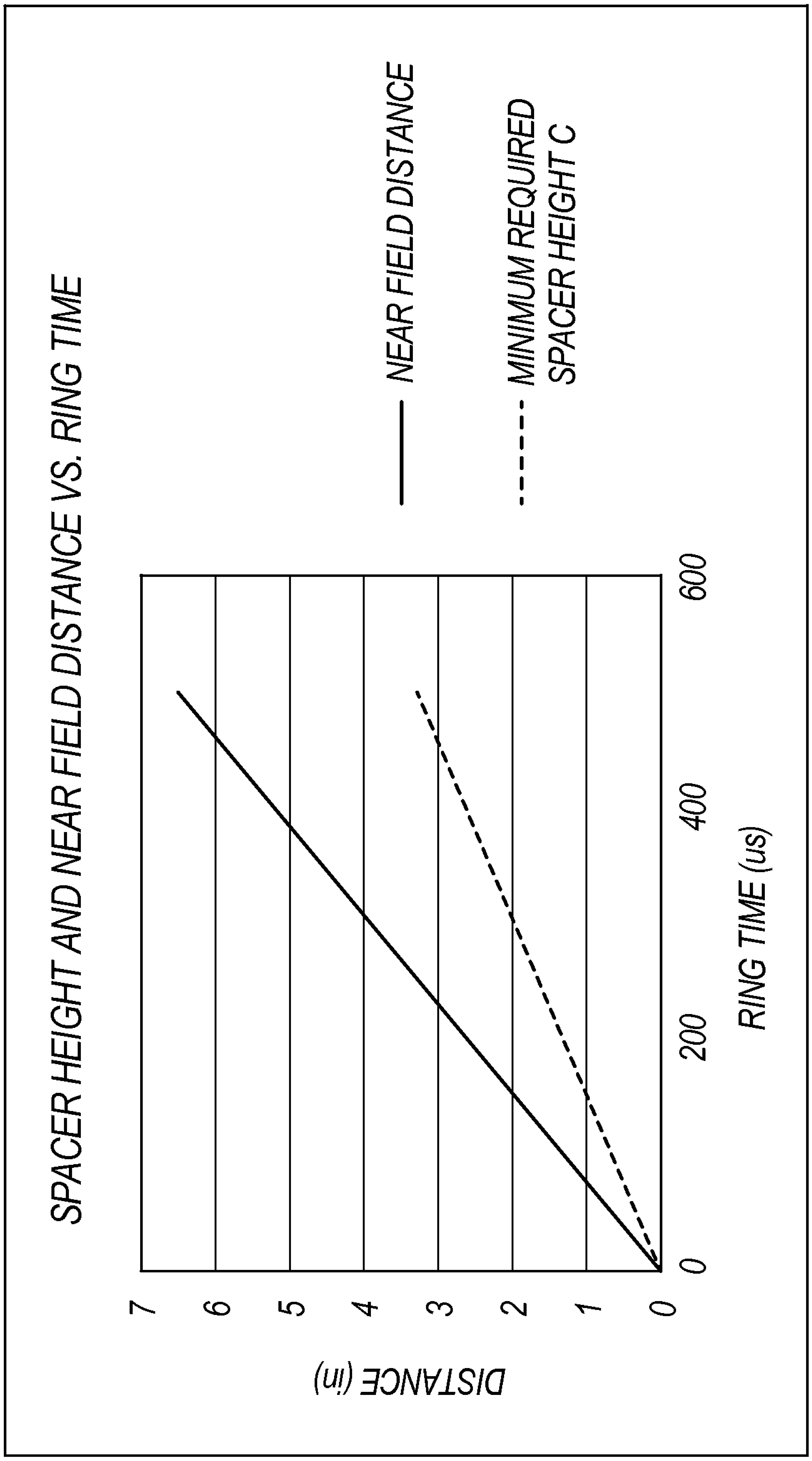
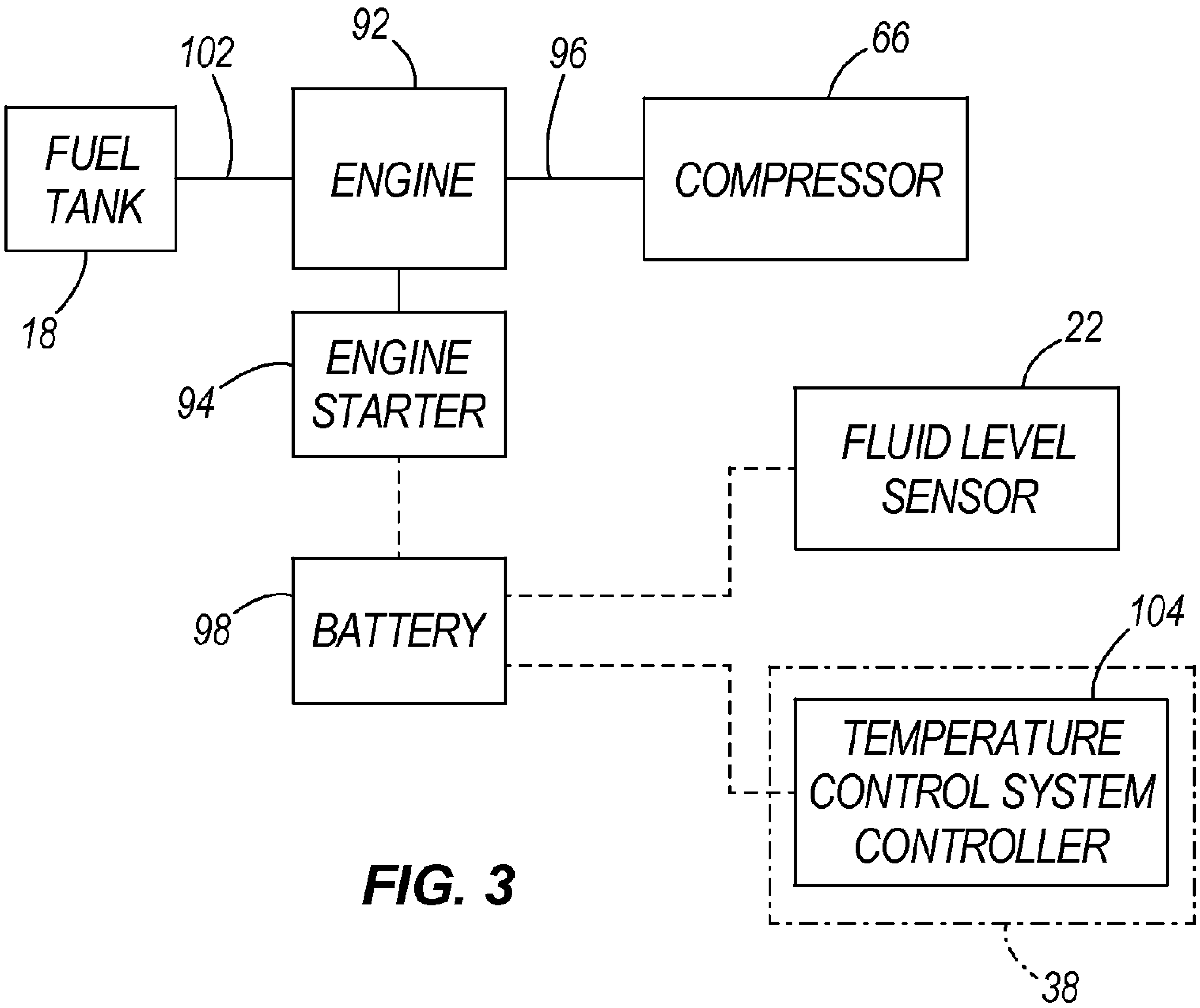
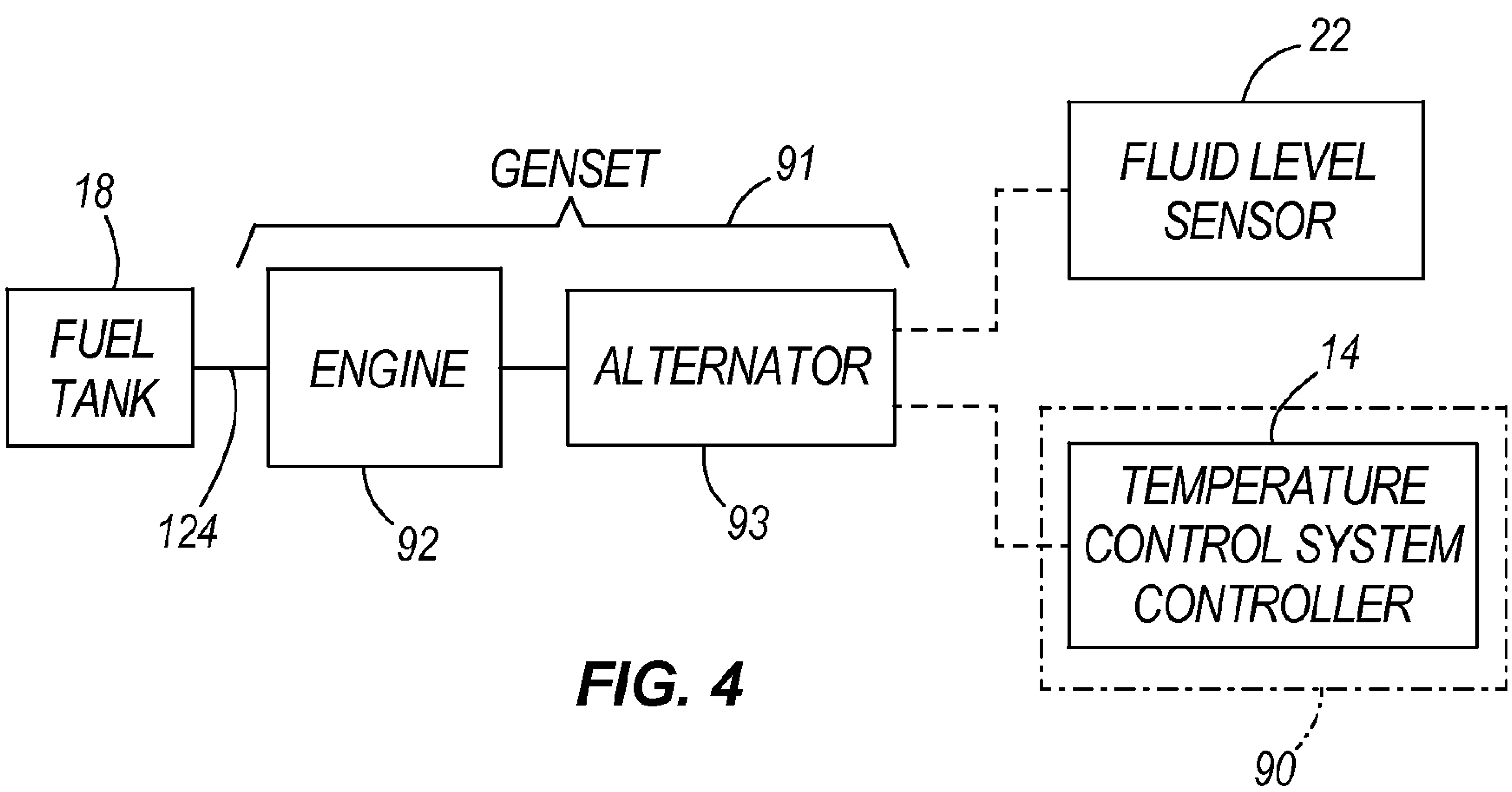

SPACER HEIGHT AND NEAR FIELD DISTANCE VS. RING TIME
NEAR FIELD DISTANCE
MINIMUM REQUIRED SPACER HEIGHT C
DISTANCE (in)
0
1
2
3
4
5
6
7
0
200
400
600
RING TIME (us)

FIG. 2



102
92
96
66
FUEL TANK
ENGINE
COMPRESSOR
18
ENGINE STARTER
94
22
FLUID LEVEL SENSOR
BATTERY
98
104
TEMPERATURE CONTROL SYSTEM CONTROLLER
38

FIG. 3



22
GENSET
91
18
FLUID LEVEL SENSOR
FUEL TANK
ENGINE
ALTERNATOR
14
TEMPERATURE CONTROL SYSTEM CONTROLLER
124
92
93
90

FIG. 4

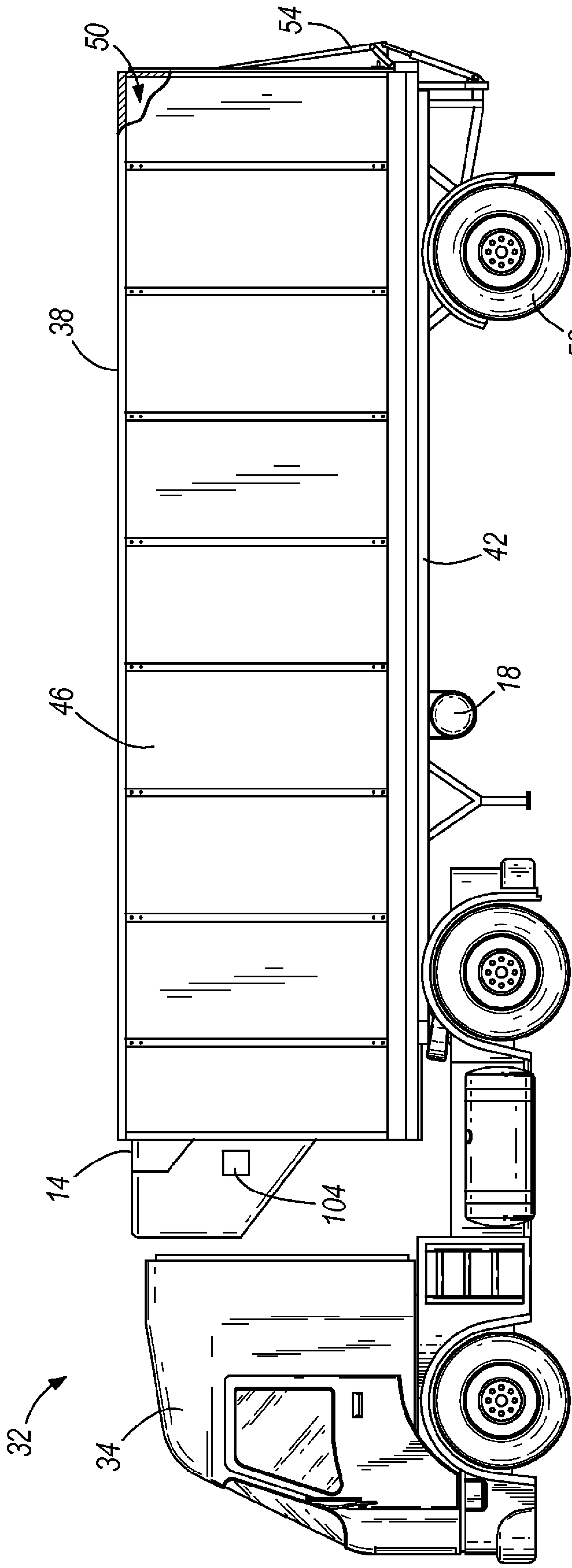


FIG. 5

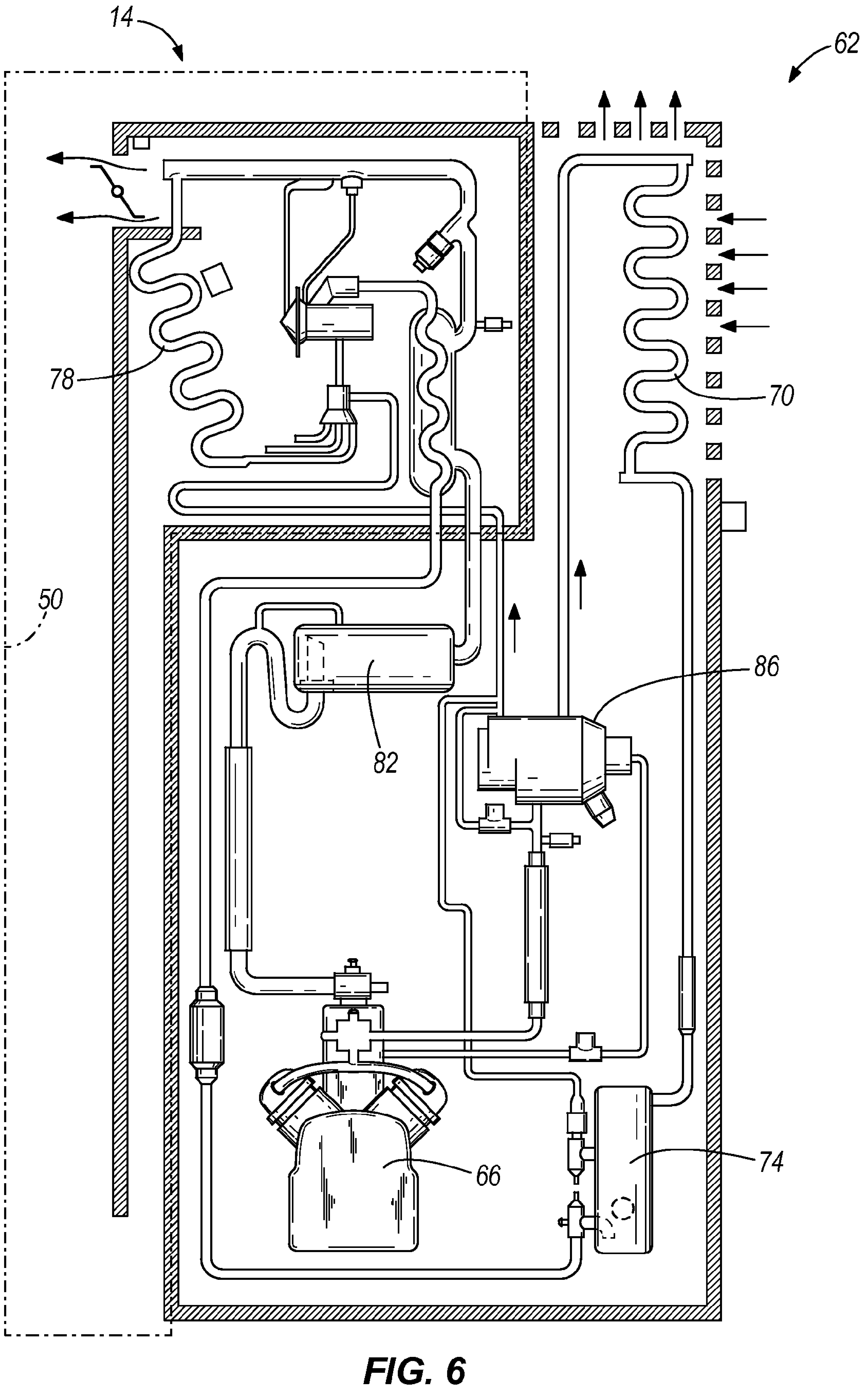


FIG. 6

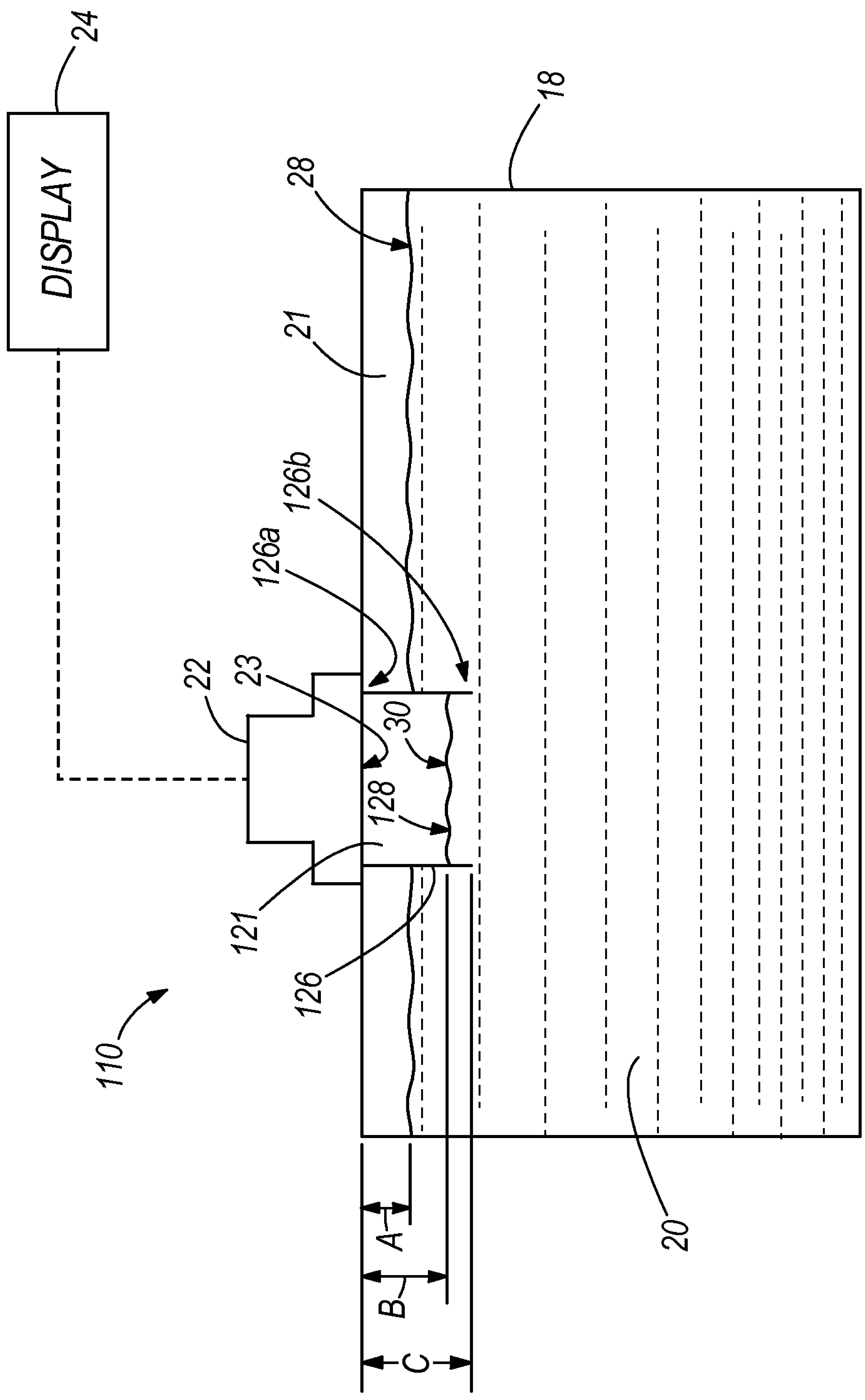


FIG. 7

FLUID LEVEL MEASUREMENT SYSTEM AND METHOD

RELATED APPLICATIONS

This patent application is a continuation of U.S. patent application Ser. No. 13/078,620, filed Apr. 1, 2011, which claims priority to U.S. Provisional Patent Application No. 61/320,033 filed on Apr. 1, 2010, the entire contents of which are both incorporated herein by reference.

BACKGROUND

The present invention relates to an apparatus and method for making ultrasonic fluid level measurements in a transport refrigeration application. Particularly, the invention relates to the position of a fluid level sensor for detecting a fuel level in a fuel tank associated with a transport temperature control system.

In a transport temperature control system application, a temperature controlled space is transported over a road, rail, sea, air or the like. As a result, fuel in a fuel tank for the temperature control system is subjected to vibrations from turbulence resulting from movement of the temperature controlled space. Furthermore, periodic stopping and starting of the temperature control system while the temperature controlled space is in transit causes periodic electrical noise associated with cranking of an engine that drives a compressor. Thus, the fluid level sensor is simultaneously subjected to vibration noise and electrical noise, which causes errors in the fluid level reading.

SUMMARY

In one aspect, the invention provides a method for measuring a fluid level in a tank containing a fluid for a transportable temperature controlled space. The method includes providing a temperature control system for the transportable temperature controlled space, providing a fluid level sensor for sensing a fluid level in the tank, generating fluid level signals with the fluid level sensor indicative of the fluid level in the tank, providing a fluid level algorithm for receiving the fluid level signals from the fluid level sensor and computing the fluid level in the tank, and inhibiting nondeterministic fluid level signals from being introduced to the fluid level algorithm.

In another aspect, the invention provides a system for measuring a fluid level in a tank for a transportable temperature controlled space. The system includes a transport temperature control system for conditioning a load space of the transportable temperature controlled space, and a fluid level measurement system for measuring the fluid level. The fluid level measurement system includes a tank containing a fluid, a fluid level sensor for generating fluid level signals indicative of the fluid level in the tank, and a fluid level algorithm for receiving the fluid level signals from the fluid level sensor and computing the fluid level in the tank. The fluid level measurement system is configured to inhibit nondeterministic fluid level signals from being introduced to the fluid level algorithm.

In yet another aspect, the invention provides a method for measuring a fluid level in a tank containing a fluid. The method includes providing a fluid level sensor for measuring a fluid level in the tank, providing a temperature control system for a transportable temperature controlled space, providing a power source, powering the fluid level sensor and the temperature control system with the same power source, generating fluid level signals with the fluid level sensor indicative of the fluid level in the tank, and inhibiting nondeterministic fluid level signals.

Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of a fluid level measurement system for a tank in accordance with the present invention.

FIG. **2** is a plot of spacer height and near field distance vs. ring time for the fluid level measurement system of FIG. **1**.

FIG. **3** is a schematic diagram of a container power system for powering the fluid level measurement system.

FIG. **4** is a schematic diagram of a trailer power system for powering the fluid level measurement system.

FIG. **5** is an image of a tractor and trailer having the tank of FIG. **1**.

FIG. **6** is a schematic diagram of a temperature control system for the trailer of FIG. **5**.

FIG. **7** is a schematic illustration of another construction of a fluid level measurement system for a tank in accordance with the present invention.

DETAILED DESCRIPTION

Before any constructions of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other constructions and of being practiced or of being carried out in various ways.

FIG. **1** illustrates a fluid level measurement system **10** for use with a transport temperature control system **14** (FIGS. **3**-**6**). The fluid level measurement system **10** includes a fluid tank **18** for containing a fluid **20** and a fluid vapor **21**, such as a fuel tank containing a fuel and fuel vapor, and a fluid level sensor **22** having a face **23**. In the illustrated construction, the tank **18** is a cylindrical diesel fuel tank coupled horizontally to a vehicle (FIG. **5**) such that a longitudinal axis thereof lies substantially parallel to the ground. A spacer **26** is coupled with the tank **18** adjacent an opening in the tank **18** and extends from the top of the tank **18**. The spacer **26** is a tubular structure having a wall extending axially from an outer surface of the tank **18** and having first and second open free ends **26***a*, **26***b*, respectively. The sensor **22** is coupled with the spacer **26** and positioned coaxially with respect to the spacer **26**. The face **23** of the sensor **22** is positioned adjacent the first free end **26***a* and the second free end **26***b* abuts the tank **18** and is in communication with an interior of the tank **18**.

In the illustrated construction, the fluid level sensor **22** is an ultrasonic fluid level sensor including a transducer that emits a sound, by way of an initial vibration, in the direction of a surface **30** of the fluid **20**, preferably in a direction perpendicular to the surface **30** of the fluid **20**. The sound is emitted from the sensor **22** at the face **23** of the sensor **22**. The sensor **22** includes a receiver that senses an echo of the initial sound reflected off the surface **30** and records a time between emitting the sound and receiving the echo. Based on the speed of sound through the medium through which the sound travels, e.g., air and fuel vapor **21**, and the recorded time, a separation distance A between the sensor **22** and the surface **30** of the fluid **20** is calculated. The system **10** includes a fluid level algorithm that is calibrated such that the distance A is associated with a fluid level of the tank. The fluid level is displayed on a display **24**.

The spacer **26** is sandwiched between the tank **18** and the sensor **22** to provide a minimum separation distance B between the sensor **22** and the surface **30** of the fluid **20** at a maximum fluid level **28**. The maximum fluid level **28** is a predetermined level that the tank **18** is designed to hold and need not be the absolute physical maximum of the tank **18**. For example, a fuel-dispensing nozzle typically shuts off automatically when the fuel reaches a fluid level that is less than the physical maximum of the tank **18**. In this case, the maximum fluid level **28** is the level at which the fuel-dispensing nozzle shuts off, and the fluid level algorithm is calibrated to associate a reading of "FULL" with the maximum fluid level **28**. The tank **18** includes a fill neck (not shown) for receiving the fuel-dispensing nozzle. The position of the fill neck (e.g., height) on the cylindrical tank **18** can also define the maximum fluid level **28**. The minimum separation distance B occurs when the fuel tank **18** is full and is the minimum distance necessary to inhibit nondeterministic signals, which lead to erroneous fluid level readings by the sensor **22**, as will be described in greater detail below. While the minimum separation distance B is constant and unique to a particular configuration of the fluid level measurement system **10**, the separation distance A is variable depending upon the level of the fluid **20**.

The minimum separation distance B is equal to, or in some constructions may be greater than, half the near field distance. The near field distance is calculated using the equation $D_{nf}=V_{sd}*T_t$, where D_{nf} is the near field distance, V_{sd} is the speed of sound through the medium through which the sound travels, e.g., the fluid vapor **21** and air, and T_t is the ring period of the transducer. As described above, the transducer emits the sound by way of an initial vibration; however, the transducer continues to vibrate at a decreasing magnitude after the initial vibration. The ring period is the time for the vibrations of the transducer to settle, or decrease, below a threshold of the sensor's receiver, i.e., to reach a magnitude of vibration that the receiver of the sensor **22** can no longer detect. In other words, the near field distance is equal to the distance that the sound travels through the medium during the ring period.

The fluid level measurement system **10** is configured based on the near field distance such that the sensor **22** is positioned at a distance from the surface **30** of the fluid **20** that is equal to or greater than half the near field distance when the tank is full **22**, as indicated by the following equation:

$$B \geq \frac{V_{sd} * T_t}{2}.$$

That is, the minimum separation distance B is equal to or greater than half the near field distance.

The spacer **26** is positioned vertically with respect to gravity and is sized to provide a spacer height C such that the sensor **22** and the surface **30** of the fluid **20** are separated by at least half the near field distance when the tank **18** is full. FIG. **2** is a plot of the minimum required spacer height C and near field distance vs. ring time, or ring period. In the illustrated construction, the spacer height C is approximately equal to the minimum separation distance B. The spacer height C depends on the construction of the tank **18**. In the illustrated construction, the sensor **22** is employed with a diesel fuel tank **18** in which the spacer **26** extends between the maximum fluid level **28** and the face of the sensor **22**, as can be seen in FIG. **1**. In other constructions, the sensor **22** may be employed with other types of tanks suited for holding fluid in mobile applications. In some constructions, other relationships between spacer height C and minimum separation distance B are possible depending on the geometry of the tank **18**. In other constructions, a spacer is not necessary to provide a sufficient minimum separation distance B between the sensor **22** and the maximum fluid level **28**.

In the illustrated construction of FIG. **1**, the sensor **22** has a ring period of 500 microseconds which corresponds to a near field distance of approximately 6.5 inches. Therefore, the minimum separation distance B is approximately 3.25 inches. Inherently, the separation distance A is greater than half the near field distance when the tank **18** is not full.

The fluid level measurement system **10** is preferably employed with a transport temperature control system fuel tank **18**, such as for a truck, a trailer, a shipping container, a rail container, a van or another transport vehicle that stores and/or carries goods that must be maintained in a temperature controlled environment. However, in other constructions, other types of tanks for other applications may be used.

In one construction, illustrated in FIGS. **3** and **5**, the fuel tank **18** and fluid level measurement system **10** are coupled to a transport vehicle **32** including a tractor **34** and trailer **38**. As shown in FIG. **5**, the trailer **38** includes a frame **42** and an outer wall **46** supported on the frame **42** for substantially enclosing a temperature controlled load space **50**. Doors **54** are supported on the frame **42** for providing access to the load space **50**. In some constructions, the load space **50** can include a partition or an internal wall for at least partially dividing the load space **50** into sub-compartments, including two or more load space zones, each of which can be maintained at a different temperature or a different humidity. A plurality of wheels **58** are provided on the frame **42** to permit movement of the vehicle **32** across the ground. In some constructions, wheels and/or rails for a railroad or a boat vessel can be used for transporting temperature controlled containers.

FIG. **6** illustrates one construction of a temperature control system **14** that conditions the load space **50** of the trailer **38**. The temperature control system **14** includes a refrigeration circuit **62** having a compressor **66**, a condenser **70**, a receiver **74**, an evaporator **78** and an accumulator **82** connected in series, as is well understood in the art. The refrigeration circuit **62** may also include other components well known in the art, such as a three-way switching valve **86** for switching between a heating mode and a cooling mode. The temperature control system is fully described in U.S. Pat. No. 6,367,269 titled "ELECTRONIC THROTTLING VALVE DIAGNOSIS AND PREVENTATIVE SHUTDOWN CONTROL," assigned to the same assignee as the present invention, the content of which is hereby fully incorporated herein by reference.

The compressor **66** is operatively coupled to an engine **92**. As shown schematically in the construction of FIG. **3**, the engine **92**, such as a diesel engine, is coupled to the compressor **66** by a transmission **96** for driving the compressor **66**. The fuel tank **18** supplies fuel to the engine **92** by way of a fuel line **102**. FIG. **3** further illustrates a power source, such as a battery **98**, for powering the fluid level sensor **22**, for powering a controller **104** for the temperature control system, and for powering an engine starter **94** for starting the engine **92** when cooling or heating is needed. Other components of the temperature control system **14** may also be powered by the battery **98**.

In other constructions, the engine **92** may include the vehicle engine or a gasoline engine. Other arrangements are possible and may be implemented, as desired. The fuel tank **18** may supply fuel to one or more of the engines employed.

FIG. **4** illustrates another construction in which the fluid level sensor **22** is employed with a temperature controlled transport container **90**. For shipments of perishable goods, the temperature control system **14** may be employed to heat and/or cool the container **90**. The transport container **90** may be transported by a variety of modes, such as by railcar, barge and truck. While the transport container **90** is stationary, such as while stored in a warehouse, on a dock, or near an airport, an external source of power such as utility electricity may be connected for powering the temperature control system **14**. If the container **90** is not provided with an external power source, a generator set **91** may be provided to power the temperature control unit **14**. For example, when the container is in transit by railcar, barge, or truck, the generator set **91** may be necessary. The generator set **91** includes the engine **92** to drive an alternator **93** which in turn provides electric power to the temperature control system **14**, specifically the compressor **66**. Thus, the engine **92** is operatively connected to the compressor **66**. The alternator **93** also provides electric power to the fluid level sensor **22**.

FIG. **7** illustrates another construction of a fluid level measurement system **110** having an internal spacer **126**. Elements of this construction that are similar to the construction of FIG. **1** are given similar reference numerals. The internal spacer **126** is positioned vertically with respect to gravity. The internal spacer **126** provides the minimum separation distance B between the face **23** of the sensor **22** and a maximum fluid level **128** of the fluid within the internal spacer **126**, which is lower than the maximum fluid level **28** of the tank **16**, by trapping an air/vapor bubble **121** inside the spacer **126** to push the maximum fluid level **128** inside the spacer **126** away from the face of the sensor **23**, much like submerging a cup upside down in water. The internal spacer **126** is a tubular structure having a wall extending axially and having first and second open free ends **126***a*, **126***b*, respectively. The face **23** of the sensor **22** is positioned adjacent the first free end **126***a* and the second free end **126***b* is in communication with the interior of the tank **18**.

The height C of the internal spacer **126** is at least equal to the minimum required spacer height shown in FIG. **2**, as discussed above, and is preferably greater than the minimum required spacer height to account for possible tilting of the tank **18** or sloshing of the fluid within the internal spacer **126**. If the tank **18** and internal spacer **126** are tilted or if sloshing occurs, the air/vapor bubble **121** may escape from the internal spacer **126**, raising the level **128** closer to the level **28**. Therefore, the actual height C of the internal spacer **126** is preferably greater than the minimum required spacer height C. For example, if the ring time of the transducer is 350 microseconds, the minimum spacer height C is approximately 2.4 inches, as plotted in FIG. **2**. The actual height of the internal spacer may be chosen to be 3.5 or 4 inches to reduce the chance of air/vapor escaping. Thus, similar to the construction described in FIG. **1**, the minimum separation distance B is equal to or greater than half the near field distance. In some constructions, the internal spacer **126** may include a flange for inhibiting the air/vapor bubble **121** from escaping.

In operation, the fluid level sensor **22** is powered by the same power source that provides power to the temperature control system **14**. In the construction of FIG. **4**, a generator set **91** provides power to the fluid level sensor **22** and the temperature control system **14**. In the construction of FIG. **3**, a battery provides power to the fluid level sensor **22** and the engine starter **94**, which starts the engine **92** to drive the compressor **66** of the temperature control system **14**. In other constructions, other types of suitable power sources may be employed.

The output power, oscillator frequency, and analog circuitry of the fluid level sensor **22** depend on a constant input voltage. During startup of the compressor **66** of the temperature control system **14**, which occurs as needed while the trailer **38** or container **90** is in transit, the power source **98**, **91** is subjected to a heavy load, e.g., cranking, causing the voltage supply to the fluid level sensor **22** to droop and be unstable (e.g., power supply noise).

While the trailer **28** or container **90** is in transit, vibrations from movement over the road or rail, or other turbulence, causes vibrations in the surface **30** of the fluid **20**. The combination of power supply noise and vibration noise in the fluid surface **30**, simultaneously, may result in a nondeterministic signal. A nondeterministic signal introduced to the fluid level algorithm results in multiple possible fluid levels being computed, causing glitches in the fluid level measurement, such as rapid changes in the fluid level reading in a short period of time, e.g., more than 4% in less than 10 seconds, when the algorithm selects the wrong fluid level out of the possible fluid levels.

When the sensor **22** is spaced from the surface **30** of the fluid **20** by at least half the near field distance, the nondeterministic signal is inhibited and glitches are avoided. Thus, the fluid level measurement system **10**, **110** is configured such that the sensor **22** is spaced from the maximum fluid level **28**, **128** of the tank **18** by at least half the near field distance such that the sensor **22** is spaced from the fluid surface **30** by a distance greater than half the near field distance when the tank **18** is not full. The spacer **26**, **126** is sized accordingly to provide the necessary minimum separation distance B.

Thus, the invention provides, among other things, a fluid level sensor spaced from a maximum fluid level of the tank by a distance greater than or equal to half the near field distance of the sensor.

What is claimed is:

1. A method for measuring a fluid level in a tank containing a fluid, the tank being included in a temperature control system for a transportable temperature controlled space, the method comprising:

sensing a fluid level in a tank using a fluid level sensor, the sensing including:

directing a fluid level signal toward a surface of the fluid such that a fluid level signal travels through a fluid vapor and air and is reflected from the surface of the fluid back toward the fluid level sensor; and

receiving the fluid level signal through the fluid vapor and air after it is reflected from the surface of the fluid;

generating fluid level signals with the fluid level sensor indicative of the fluid level in the tank;

receiving the fluid level signals from the fluid level sensor;

computing the fluid level in the tank, using a controller for the temperature control system, based on the fluid level signals received from the fluid level sensor; and

inhibiting nondeterministic fluid level signals from being introduced by positioning the fluid level sensor a distance from a maximum fluid level, the distance being half the distance that sound travels through the fluid vapor and air toward the surface of the fluid during a ring period of the fluid level sensor.

2. The method of claim **1**, further comprising:

powering both the fluid level sensor and the temperature control system with a power source.

3. The method of claim **2**, further comprising:

subjecting the fluid level sensor to power supply noise.

4. The method of claim **3**, further comprising:

inhibiting nondeterministic fluid level signals from being introduced while subjecting the fluid level sensor to power supply noise.

5. The method of claim **4**, further comprising:

receiving a fuel for the temperature control system in the tank.

6. The method of claim **4**, wherein the powering the temperature control system includes powering an engine starter for an engine.

7. The method of claim **4**, wherein the powering the fluid level sensor and the temperature control system with the same power source includes powering the fluid level sensor and the temperature control system with at least one of a battery and an alternator.

8. The method of claim **2**, further comprising:

receiving a fuel for the temperature control system in the tank.

9. The method of claim **8**, wherein the powering the temperature control system includes powering an engine starter for an engine configured to receive the fuel from the tank.

10. The method of claim **2**, wherein the powering the fluid level sensor and the temperature control system with the same power source includes powering the fluid level sensor and the temperature control system with at least one of a battery and an alternator.

11. A system for measuring a fluid level in a tank for a transportable temperature controlled space, the system comprising:

a transport temperature control system for conditioning a load space of the transportable temperature controlled space; and

a fluid level measurement system for measuring the fluid level comprising:

a tank containing a fluid;

a fluid level sensor configured to be directed toward a surface of the fluid configured to generate fluid level signals indicative of the fluid level in the tank, wherein the fluid level signals from the fluid level sensor are reflected from the surface of the fluid;

the fluid level sensor positioned a distance from the maximum fluid level, the distance being about half the distance that sounds travels through the fluid vapor and air toward the surface of the fluid during a ring period of the fluid level sensor; and

a controller configured to receive the fluid level signals from the fluid level sensor and compute the fluid level in the tank, wherein the fluid level measurement system is configured to inhibit nondeterministic fluid level signals from being introduced.

12. The system of claim **11**, further comprising:

a power source coupled to both the fluid level sensor and the temperature control system, the power source configured to power the fluid level sensor and the temperature control system.

13. The system of claim **12**, wherein the temperature control system further comprises:

a compressor for compressing a refrigerant, and

wherein the tank is a fuel tank configured to provide a fuel to the compressor.

14. The system of claim **13**, wherein the temperature control system further comprises:

an engine configured to drive the compressor; and

an engine starter configured to start the engine,

wherein the power source is configured to power the engine starter.

15. The system of claim **14**, wherein the power source includes at least one of a battery and an alternator.

16. A method for measuring a fluid level in a tank containing a fluid, the tank being included in a temperature control system for a transportable temperature controlled space, the method comprising:

Measuring a fluid level in the tank using a fluid level sensor, the measuring including:

directing a fluid level signal toward a surface of the fluid such that a fluid level signal travels through a fluid vapor and air and is reflected from the surface of the fluid back toward the fluid level sensor; and

receiving the fluid level signal through the fluid vapor and air after it is reflected from the surface of the fluid;

powering the fluid level sensor and the temperature control system with the same power source;

generating fluid level signals with the fluid level sensor indicative of the fluid level in the tank; and

inhibiting nondeterministic fluid level signals by positioning the fluid level sensor a distance from the maximum fluid level, the distance being about half the distance that sound travels through the fluid vapor and air toward the surface of the fluid during a ring period of the fluid level sensor.

17. The method of claim **16**, further comprising:

receiving the fluid level signals from the fluid level sensor; and

computing the fluid level in the tank, using a controller for the temperature control system, based on the fluid level signals received from the fluid level sensor.

18. The method of claim **17**, further comprising:

inhibiting nondeterministic fluid level signals from being received by the controller.

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